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WO 1997/044980 A1 US 5559829 A
US 20020118698 A1
IEEE 4th International Symposium on Spread Spectrum
Techniques and Applications, Elders-Boll et al.,
"Interference Parameters of Concatenated Spreading
Sequences For Asynchronous CDMA", 22-25 Sept.
1996

(58) Field of Search:
UK CL (Edition V) **H4P**
INT CL⁷ **H03M, H04B, H04J, H04L**
Other: **Online: WPI, EPODOC, PAJ, INSPEC and**
selected internet sites

(54) Abstract Title: **Sequence production in a spread spectrum communication system**

(57) An efficient scheme (300) for CDMA coding constructs codes by generating longer code sequences of a predetermined length via concatenation (330) of selected short sequences, selected from an existing set (320). The sequences may be spreading, scrambling and/or training or channel estimation (such as midamble) sequences.

This provides the following advantages:

- allows extension of sequences without performing an exhaustive search for sequences with optimal desired properties.
- provides a simple means of extending the sequence duration that is able to re-use the existing hardware/software/ROM, etc., and only requires the addition of a simple programmable or fixed selection algorithm.
- extends the sequence duration to improve the detection of wanted signals via the use of a conventional matched filter, a multi-user detector or an adaptive filter/equaliser.

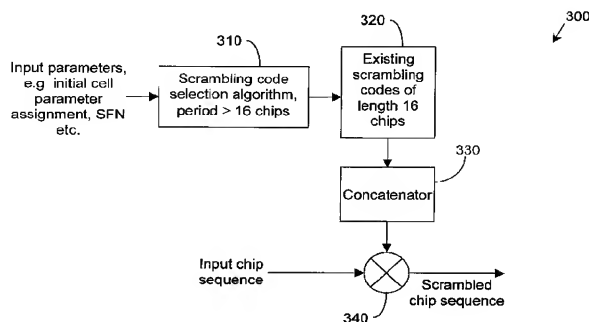


FIG. 3

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

This print takes account of replacement documents submitted after the date of filing to enable the application to comply with the formal requirements of the Patents Rules 1995

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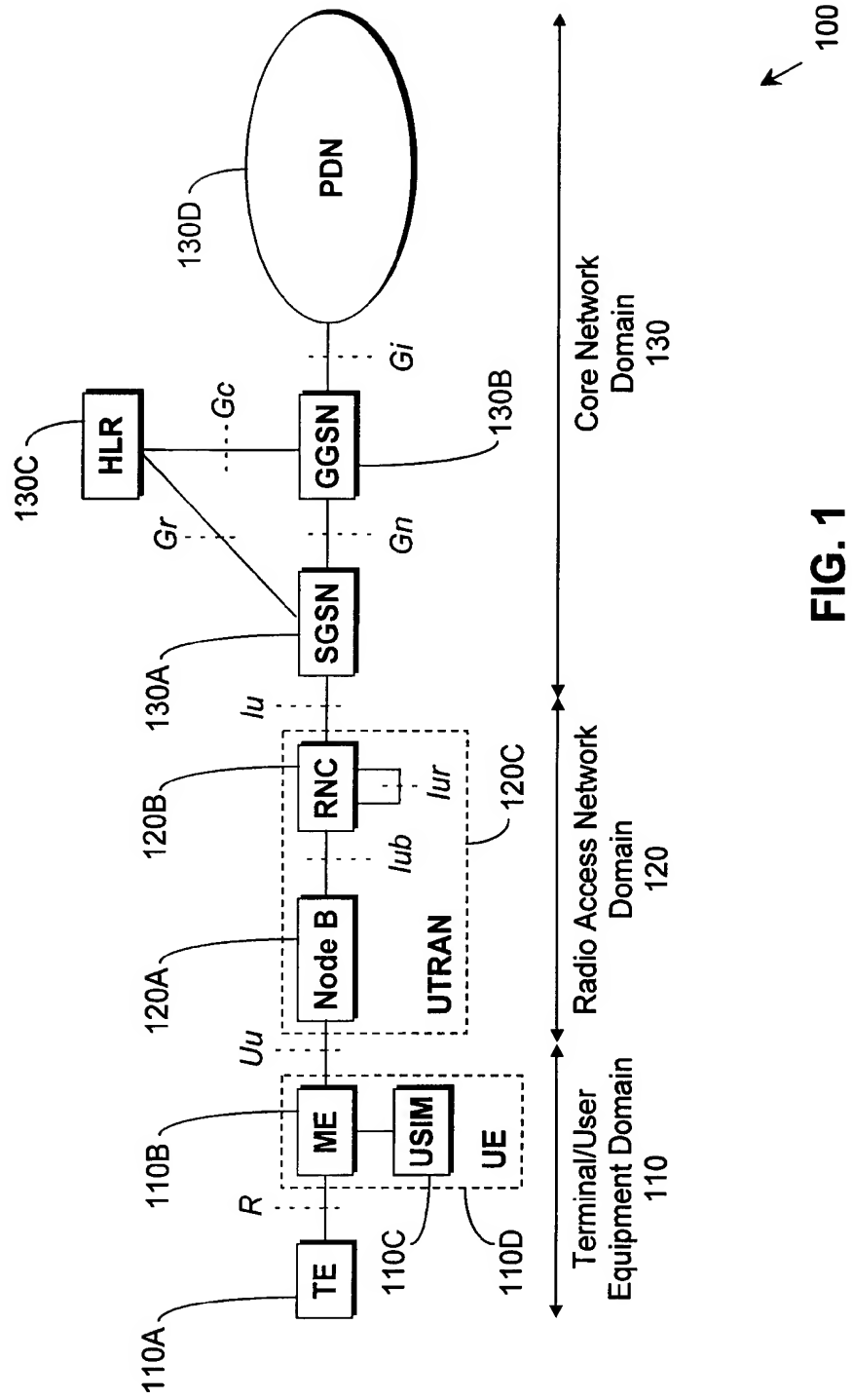


FIG. 1



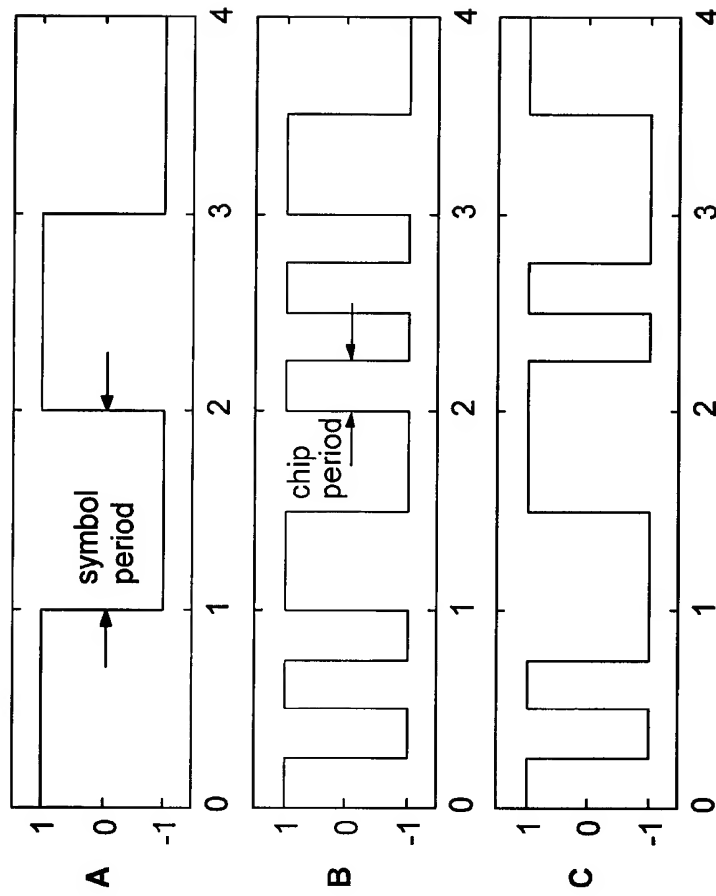


FIG. 2

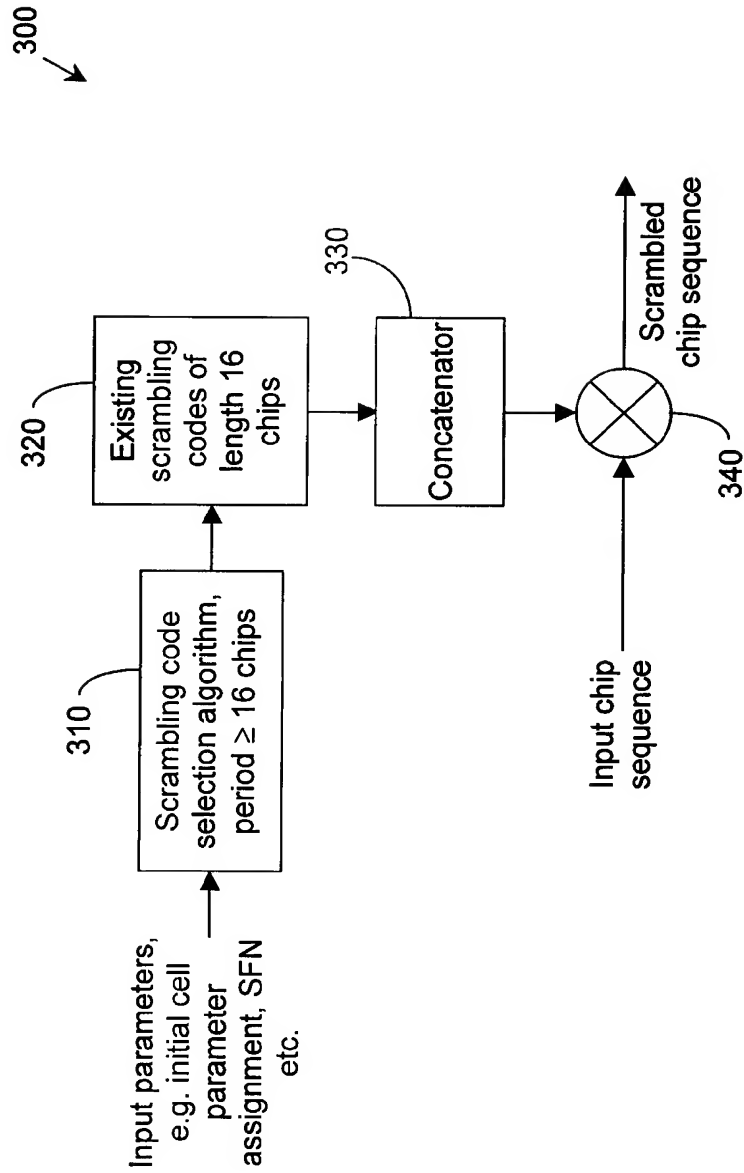
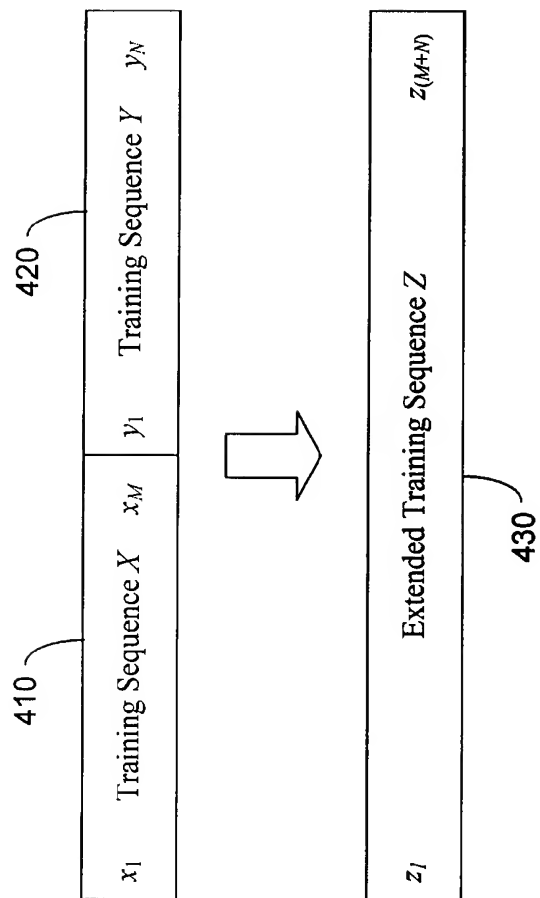


FIG. 3



ARRANGEMENT AND METHOD FOR SEQUENCE PRODUCTION IN A
SPREAD SPECTRUM COMMUNICATION SYSTEM

5 Field of the Invention

This invention relates to spread spectrum communication systems, and particularly (though not exclusively) to direct sequence (DS) spread spectrum wireless
10 communication systems.

Background of the Invention

15 In DS spread spectrum communications such as in code division multiple access (CDMA) systems, a signal for transmission is spread in the frequency domain. Thus the same information is transmitted over a different (larger) bandwidth, affording some level of diversity in the
20 frequency domain. The benefits of such a communications method are that the transmitted signal is more resilient to band limited interference and frequency selective fading.

25 The spreading of a signal is achieved by modulating each symbol, or each set of consecutive symbols, of the transmission signal by a sequence or code that varies at a faster rate than that of the transmission signal. Typically in DS-CDMA systems the spreading waveforms are
30 selected from a long pseudo random sequence, or if short enough they can be chosen according to some optimality

criteria. Whilst longer sequences are desirable due to their superior correlation properties, shorter sequences are typically employed due to the resulting ease of implementation of both transmitter and receiver algorithms and associated hardware. As an example of a method for the design of short sequences, but not restricted to this method, the sequences may be chosen such that they exhibit good auto-correlation properties or such that pairs of sequences exhibit favourable cross-correlation properties. This typically requires a search over all possible sequences of the desired length to select the sequences with the desired attributes. For each new spreading length required, a new search is required for sequences that satisfy the desired optimality criteria.

However, this approach has the disadvantage(s) that, since good spreading waveform sequences require a search over all possible sequences of a desired length to select the sequences with the desired attributes, and since for each new spreading length required a new search is required for sequences that satisfy the desired optimality criteria, longer sequence lengths are inefficient to design.

25

A need therefore exists for efficient spread spectrum code construction wherein the abovementioned disadvantage(s) may be alleviated.

Statement of Invention

In accordance with a first aspect of the present invention there is provided an arrangement, for producing
5 a sequence of a predetermined length in a spread spectrum communication system, as claimed in claim 1.

In accordance with a second aspect of the present invention there is provided a method, of producing a
10 sequence of a predetermined length in a spread spectrum communication system, as claimed in claim 12.

The invention allows efficient generation of longer sequences from shorter ones. This has the advantage of
15 alleviating the need for an extensive search of sequences of the desired length and allows the simple re-use of existing hardware. The invention is suitable for any purposes where a set of sequences are used to derive a set of extended sequences with longer duration than the
20 original sequences. The invention is applicable to TD-CDMA systems, and in particular the various chip rates of the TDD mode of UTRA. The reader will appreciate that this method is applicable to, but not restricted to, generating extended length spreading sequences,
25 scrambling sequences and channel estimation sequences or midambles.

Brief Description of the Drawing(s)

Two efficient CDMA code construction schemes
incorporating the present invention will now be
5 described, by way of example only, with reference to the
accompanying drawings, in which:

FIG. 1 shows a block schematic diagram illustrating
a 3GPP UTRA radio communication system in which the
10 present invention may be used;

FIG. 2 shows a schematic diagram illustrating
spreading of data symbols in direct sequence spread
spectrum; and
15

FIG. 3 shows a block schematic diagram illustrating
an arrangement for concatenation of scrambling codes
in UTRA TDD mode incorporating the present
invention; and
20

FIG. 4 shows a block schematic diagram illustrating
generation of an extended training code (such as a
midamble) by concatenation of shorter training
codes.
25

Description of Preferred Embodiments

Referring firstly to FIG. 1, a typical, standard UMTS
30 Radio Access Network (UTRAN) system 100 is conveniently
considered as comprising: a terminal/user equipment

domain 110; a UMTS Terrestrial Radio Access Network domain 120; and an infrastructure domain 130.

In the terminal/user equipment domain 110, terminal
5 equipment (TE) 110A is connected to user mobile equipment (ME) 110B via the wired or wireless *R* interface. The ME 110B is also connected to a user service identity module (USIM) 110C; the ME 110B and the USIM 110C together are considered as a user equipment (UE) 110D. The UE 110D
10 communicates data with a Node B (base station) 120A in the radio access network domain (120) via the wireless *Uu* interface. Within the network radio access network domain 120, the Node B 120A communicates with a radio network controller (RNC) 120B via the *Iub* interface. The
15 RNC 120B communicates with other RNC's (not shown) via the *Iur* interface. The Node B 120A and the RNC 120B together form the UTRAN 120C. The RNC 120B communicates with a serving GPRS service node (SGSN) 130A in the core network domain 130 via the *Iu* interface. Within the core
20 network domain 130, the SGSN 130A communicates with a gateway GPRS support node 130B via the *Gn* interface; the SGSN 130A and the GGSN 130B communicate with a home location register (HLR) server 130C via the *Gr* interface and the *Gc* interface respectively. The GGSN 130B
25 communicates with public data network 130D via the *Gi* interface.

Thus, the elements RNC 120B, SGSN 130A and GGSN 130B are conventionally provided as discrete and separate units
30 (on their own respective software/hardware platforms)

divided across the radio access network domain (120) and the core network domain (130), as shown in FIG. 1.

The RNC 120B is the UTRAN element responsible for the control and allocation of resources for numerous Node B's 120A; typically 50 to 100 Node B's may be controlled by one RNC. The RNC also provides reliable delivery of user traffic over the air interfaces. RNC's communicate with each other (via the *Iur* interface) to support handover.

The SGSN 130A is the UMTS Core Network element responsible for Session Control and interface to the HLR. The SGSN keeps track of the location of an individual UE and performs security functions and access control. The SGSN is a large centralised controller for many RNCs.

The GGSN 130B is the UMTS Core Network element responsible for concentrating and tunnelling user data within the core packet network to the ultimate destination (e.g., internet service provider - ISP).

Such a UTRAN system and its operation are described more fully in the 3rd Generation Partnership Project technical specification document 3GPP TS 23.060, and related documents, available from the 3GPP website at www.3gpp.org, and need not be described herein in more detail.

In time division code division multiple access (TD-CDMA) systems, such as the time division duplex (TDD) mode of UMTS Terrestrial Radio Access (UTRA), the spreading

assignment is even and as the initial cell parameter
assignment minus 1 if the initial cell parameter
assignment is odd. The scrambling code may span either
1, 2, 4, 8 or 16 symbols depending upon the channelisation
5 code employed. Thus in this system the spreading code
can be viewed as composite of the channelisation code and
the scrambling code.

The spreading of signals in a 3GPP TDD system is
10 described in detail in the 3GPP technical specification
document 3GPP TS 25.223, 'Spreading and Modulation
(TDD)', available from the 3GPP website at www.3gpp.org,
and need not be described herein in more detail.

15 As will be described in more detail below, the present
invention is based on a flexible approach (alternative to
the prior art approach described above) for the
generation of longer sequences from short ones by
concatenating two or more short sequences according to
20 the desired length of the new sequences. Whilst the new
extended sequences may not necessarily be optimal with
respect to any of the usual criteria such as auto- or
cross-correlation properties they have the distinct
advantage that they re-use an existing set of sequences
25 that can be extended for other applications. The
method's simplicity alleviates the need for a new and
exhaustive search for sequences of the desired length and
allows the re-use of existing hardware for the new
application, i.e., instead of storing or implementing
30 hardware/software for the generation of the new
sequences, a simple algorithm may be implemented that

uses the existing hardware/software for the generation of short sequences.

The number of short sequences used in the concatenation
 5 is dependent upon the desired length of the new
 sequences. The choice of sequences for concatenation may
 be flexible and may be chosen according to a simple set
 of design rules. For instance, if a set of N short
 sequences exists, each time a longer sequence is required
 10 an initial index into N of n is selected (according to
 some rules). Then according to the desired length of the
 new sequences concatenation may, for example, be produced
 from: short sequence n and $n+1$ (for a doubling of sequence
 length), or $n, n+1, n+2$ (for a tripling of sequence
 15 length) and $n, n+1, n+2, n+3$ for a quadrupling of sequence
 length. If at any point the index $n+x$ (for some x)
 exceeds the number of short sequences N the index may be
 wrapped round to the beginning of the list of short
 codes; thus $(n+x) \text{ modulo } N$ is used as the index into the
 20 list of short sequences where the index into the list of
 short sequences runs from 0 to $N-1$.

It may of course be understood that in choosing the short
 sequences for concatenation it is not necessary for the
 25 index to be incremented by 1 each time. It may in fact
 be incremented by any integer, including 0. For
 instance, in doubling the sequence length short codes n
 and $n+y$ (where $y \geq 1$) may be concatenated. Thus, for the
 tripling of the sequence length short sequences $n, n+y,$
 30 $n+2y$ may be concatenated, and for the quadrupling of the

sequence length short sequences n , $n+y$, $n+2y$, $n+3y$ may be concatenated. It may further be understood that the incremental index is not restricted to being regular and could in fact be random. For instance a tripling of
5 sequence length may be chosen by the concatenation of short sequences n , $n+y$, $n+z$ where z is not necessarily equal to a multiple of y .

As described above, the spreading sequence extension
10 scheme requires two mechanisms in order to operate:

1. A set of existing short spreading sequences.
2. An algorithm for selecting a number of the short spreading sequences from the set, in order that they may be concatenated to form a longer
15 spreading sequence.

As will be appreciated, the sequence extension scheme may be utilised in the UE and/or Node B in order to generate sequences that may be used for amongst other purposes to
20 spread data with the generated codes, or scramble data with the generated codes or used as extended channel estimation sequences.

As a more specific example of the method, but not
25 restricted to this case, the length of scrambling sequences specified in the UTRA high chip rate TDD mode may be extended. Such an extension could be applied to the specified chip rate or may be required for instance if the TDD mode were to be operated at a multiple of the
30 chip rate in the current specification. Extending the length of the scrambling codes in this scenario improves

- It will be appreciated that the method of producing a sequence described above may be carried out in software running on a processor (not shown) in a base station
- 5 (Node B) or UE, and that the software may be provided as a computer program element carried on any suitable data carrier (also not shown) such as a magnetic or optical computer disc.
- 10 It will be also be appreciated that the method of producing a sequence described above may alternatively be carried out in hardware, for example in the form of an integrated circuit (not shown) such as an FPGA (Field Programmable Gate Array) or ASIC (Application Specific
- 15 Integrated Circuit) in the Node B or UE.

It will further be understood that the efficient CDMA sequence construction scheme described above may be

20 applied to any sequence, such as a spreading sequence, a scrambling sequence or a channel estimation or training sequence (e.g., a midamble).

Referring now also to FIG. 4, a second preferred

25 embodiment of the present invention relates to the concatenation of training sequences for the purpose of channel estimation. As shown in FIG. 4, a training sequence X 410 of length M is concatenated with another training sequence Y 420 of length N to form a new

30 training sequence Z 430 of length $M+N$. It will of course be appreciated that training sequence X may be the

same as training sequence Y and that the concatenation is not restricted to two existing training sequences but rather any positive integer number of channel estimation or training sequences.

5

Training sequences may be concatenated to produce longer or extended training sequences resulting in an improved carrier to interference (C/I) ratio (where interference is taken as including interference and background noise) at the output of the channel estimator. Obviously the benefits of using existing shorter training sequences and concatenating them to form longer ones still apply in terms of simplicity of design and reuse of existing hardware, software, ROM etc.

15

It will be understood that the method is not restricted to the concatenation of two training sequences but rather any number of training sequences. Furthermore it will be understood that the some or all of the training sequences used for concatenation may be the same as each other. In the case where the training sequences are identical soft combining on the output of the channel estimator is performed in order to realise the additional gain in C/I.

25

A further point to note is that the entire length of the existing training sequences may not necessarily be used in the concatenation process. For instance, if the training sequence comprises a base sequence which is periodically extended, the base sequences may be used as the existing training sequences for concatenation.

30

It will be understood that the efficient CDMA sequence construction scheme described above provides the following advantages:

- 5 • allows extension of sequences without performing an exhaustive search for sequences with optimal desired properties.
- 10 • provides a simple means of extending the sequence duration that is able to re-use the existing hardware/software/ROM, etc., and only requires the addition of a simple programmable or fixed selection algorithm.
- 15 • extends the sequence duration to improve the detection of wanted signals via the use of a conventional matched filter, a multi-user detector or an adaptive filter/equaliser.

Claims

1. An arrangement for producing a sequence of a predetermined length in a spread spectrum communication
 5 system, the arrangement comprising:

a plurality of predetermined sequences having lengths less than the predetermined length;

means for selecting at least two of the plurality of predetermined sequences; and

10 means for concatenating the selected at least two of the plurality of predetermined sequences to produce the predetermined length sequence.

2. The arrangement of claim 1 wherein

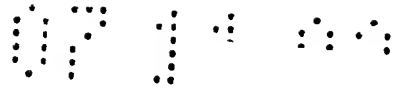
15 the plurality of predetermined sequences are arranged in an indexed list; and

the means for selecting comprises:

means for selecting a first sequence of the at least two of the plurality of
 20 predetermined sequences with an index value of n from the list; and

means for selecting each successive sequence of the at least two of the plurality of predetermined sequences with an index value
 25 incremented from that of the previously selected sequence from the list.

3. The arrangement of claim 2 wherein the increment is a predetermined integer.



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4. The arrangement of claim 3 wherein the predetermined integer is one of: 0, 1 and 2.
5. The arrangement of claim 2 wherein the increment is randomly chosen for each successive sequence.
6. The arrangement of any one of claims 2-5 wherein n is determined from at least one of A-F:
 - A initial cell parameter assignment,
 - 10 B system frame number (SFN),
 - C chip rate of transmission,
 - D predetermined length of spreading code,
 - E identifier of intended receiver of data spread with the predetermined length spreading code,
 - 15 F channelisation code employed.
7. The arrangement of any one of claims 1-6 wherein the plurality of predetermined sequences have a length of 16 chips.
- 20 8. The arrangement of any one of claims 1-7 wherein the spread spectrum communication system comprises a DS-CDMA UMTS system.
- 25 9. The arrangement of claim 8 wherein the system comprises a UTRA TDD system.
10. The arrangement of any one of claims 1-8 wherein the sequence is one of:
 - 30 a spreading sequence,
 - a scrambling sequence and

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a midamble.

11. The arrangement of any one of claims 1-9 further comprising:

5 means for processing data with the predetermined length sequence.

12. A method of producing a sequence of a predetermined length in a spread spectrum communication system, the method comprising:

5 providing a plurality of predetermined sequences having lengths less than the predetermined length;

selecting at least two of the plurality of predetermined sequences;

10 concatenating the selected at least two of the plurality of predetermined sequences to produce the predetermined length sequence.

13. The method of claim 12 wherein

15 the step of providing comprises providing the plurality of predetermined sequences in an indexed list; and

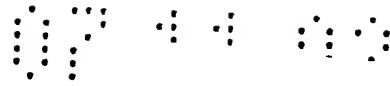
the step of selecting comprises:

20 selecting a first sequence of the at least two of the plurality of predetermined sequences with an index value of n from the list; and

25 selecting each successive sequence of the at least two of the plurality of predetermined sequences with an index value incremented from that of the previously selected sequence from the list.

14. The method of claim 13 wherein the increment is a predetermined integer.

30 15. The method of claim 14 wherein the increment is one of: 0, 1 and 2.



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16. The method of claim 13 wherein the increment is randomly chosen for each successive sequence.
- 5 17. The method of any one of claims 12-16 wherein n is determined from at least one of A-F:
- A initial cell parameter assignment,
 - B system frame number (SFN),
 - C chip rate of transmission,
 - 10 D predetermined length of spreading code,
 - E identifier of intended receiver of data spread with the predetermined length spreading code,
 - F channelisation code employed.
- 15 18. The method of any one of claims 12-17 wherein the plurality of predetermined sequences have a length of 16 chips.
19. The method of any one of claims 11-17 wherein the
20 spread spectrum communication system comprises a DS-CDMA UMTS system.
20. The method of claim 19 wherein the UMTS system comprises a UTRA TDD system.
- 25 21. The method of any one of claims 12-20 further comprising:
- processing data with the predetermined length sequence.

30

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22. A base station for use in a CDMA system, the base station comprising the arrangement of any one of claims 1-11.

5 23. User equipment for use in a CDMA system, the user equipment comprising the arrangement of any one of claims 1-11.

23. A computer program element comprising computer
10 program means for performing substantially the method of any one of claims 12-21.

24. An integrated circuit comprising substantially the arrangement of any one of claims 1-11.

15

25. An arrangement, for producing a sequence of a predetermined length in a code division multiple access (CDMA) system, substantially as hereinbefore described with reference to the accompanying drawings.

20

26. A method, of producing a sequence of a predetermined length in a code division multiple access (CDMA) system, substantially as hereinbefore described with reference to the accompanying drawings.



INVESTOR IN PEOPLE

Application No: GB 0225495.1
Claims searched: 1-26

Examiner: Adam Tucker
Date of search: 4 March 2003

Patents Act 1977 : Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	1-4, 8-15, 19-24	US 5559829 (Le Strat et al.) See in particular col 1 line 47-col 2 line 21, col 3 line 50-col 4 line 5 and col 5 line 60-col 6 line 36
X	1, 7-12, 19-24	US 20020118698 A1 (Koo et al.) See in particular paras 3, 10, 20, 26, 40 and 57-63
A	-	WO 97/44980 A1 (Nokia) See in particular the summary of the invention, page 5 lines 12-16 and claims 1-6
X	1, 12 at least	IEEE 4 th International symposium on spread spectrum techniques and applications, Elders-Boll et al., "Interference parameters of concatenated spreading sequences for asynchronous CDMA", 22-25 Sept. 1996

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^v:

H4P

Worldwide search of patent documents classified in the following areas of the IPC⁷:

H03M, H04B, H04J, H04L

The following online and other databases have been used in the preparation of this search report:

WPI, EPODOC, PAJ, INSPEC and selected internet sites